ELECTROSTATIC DISCHARGE

CONTENTS PAGE

1. GENERAL 1
- What is ESD? 1
- What Causes ESD? 2
- Who Causes ESD? 2

2. DEVICE SUSCEPTIBILITY 3

3. EQUIPMENT SUSCEPTIBILITY 3

4. PREVENTIVE MEASURES 3

5. WRIST STRAPS 4

6. ANTISTATIC PACKAGING MATERIALS 4

7. ENVIRONMENTAL REQUIREMENTS 5
- Relative Humidity 5
- Floor Treatment 5
- Air Filtration 6

8. STORAGE, MOVEMENT WITHIN OFFICE, AND SHIPPING 6
- Storage 6
- Movement Within Office 6
- Shipment 7

9. REPAIR LOCATIONS OR WORK STATIONS 7

10. STRESS TESTING 8

Tables

Table 1-Triboelectric Series 9

Table 2-Items That Generate Electrostatic Charges 10

Table 3-Susceptibility Ranges of Various Unprotected Devices Subjected to Electrostatic Discharge 11

CONTENTS PAGE

Figures

Figure 1-Samples of Labels 12

Figure 2-Wrist Strap Test Method 13

1. GENERAL

1.01 This practice describes what electrostatic discharge (ESD) is and how it can be controlled by using preventive measures.

1.02 Whenever this practice is reissued, the reason for reissue will be specified in this paragraph.

1.03 The probability of damage or destruction from ESD is much greater than most people realize. Very often, ESD damage goes unnoticed because the threshold for human sensation can range from 1500 to 3500 volts. ESD damage to electronic devices can easily occur at less than 1000 volts. For this reason an individual may not feel a "shock", but electronic devices will.

• What is ESD?

1.04 ESD is a suddenly released charge frequently associated with static electricity. The most familiar example of this is the "shock" one might receive upon touching a metal object after walking across a carpeted room, particularly during the normal heating (low humidity) season. At lower levels of static charge there may be no sensation indicating that ESD has taken place, but the energy flow may be sufficient to damage or destroy a static-sensitive device or an integrated circuit. A static charge of several thousand volts can be produced by friction and retained by the human body. Static discharge occurs when the static charged person touches another person, a metal of a different potential, or a grounded object. Static charging is a natural phenomenon with extremely complex characteristics depending on material composition and structure, environment, and conditions of contact.

PROPRIETARY - BELLCORE AND AUTHORIZED CLIENTS ONLY
This document contains proprietary information that shall be distributed or routed only within Bell Communications Research (Bellcore) and its authorized clients, except with written permission of Bellcore.
Copyright ' 1985 Bell Communications Research, Inc.
All rights reserved.

1.05 Damage or degradation to electronic equipment by ESD is caused when a charged object, usually a person, makes contact and discharges the stored body charge into the equipment. It can also be caused by noncontact (induction) from a surrounding electric field. In addition, electronic devices can accumulate a static charge during transport which, upon discharge to ground, can produce damage. Total isolation or shielding of people, equipment or circuits to protect against ESD is not as yet possible.

• What Causes ESD?

1.06 A static charge is generated whenever two different materials come into contact or are rubbed together and then separated. This action results in a charge buildup due mainly to the transfer of electrons from one material to the other. The accumulation of charge causes a static potential to develop. ESD occurs when the accumulated charge is discharged to anything with a different electric potential.

1.07 The accumulation of static charge and its tendency to cover all conducting surfaces is what sets the stage for ESD damage. If a charged object contacts an uncharged object, the charge will be transferred to equalize the potential. It is important to note that we are not necessarily talking about a voltage with respect to ground, but rather a voltage or potential difference between any two objects.

1.08 The magnitude of the developed charge depends on the materials' properties, the method of charge generation, and the rate of leakage. When the rate of generation equals the rate of leakage, no further charge can be developed. The time the charge remains on a charged object depends on the conductivity of the materials and the rate of leakage.

1.09 The behavior of materials regarding static charge can be determined by their relative position in what is known as the Triboelectric Series. Table 1 shows the Triboelectric Series of some common materials. The polarity (+ or —) of the static charge generated on each of the materials and the relative magnitude of the charge can be obtained from Table 1. The farther apart the materials are located in the Triboelectric Series, the greater the static charge they can develop. A material at the top of the listing acquires a positive charge when contacted with any material below it. A classic example is rubbing a glass rod with wool. The glass assumes a positive charge and the wool a negative charge. As indicated in Table 1, many of the materials are commonly used in the semiconductor industry by both manufacturers and users.

1.10 A person walking across a floor, sliding on a chair, or rubbing a work surface can generate thousands of volts of static potential. Devices or circuit packs sliding around in containers can also develop damaging static potentials. The static charge level or potential that can be generated is affected by such factors as relative humidity, air flow rate, floor materials, furniture, clothing, and individuals. These factors exist in almost every situation. In dry conditions, such as in a heated building during the normal heating season or in naturally arid climates, the leakage rate is reduced and extremely high static potentials can be developed.

1.11 Other factors which affect the charge level are not so apparent. These include the design of manufacturing equipment and the materials used in the construction of such equipment, chemicals and other materials used in manufacturing processes, and packing and shipping materials. Table 2 lists some common items which generate electrostatic charges.

• Who Causes ESD?

1.12 Everyone who has contact with circuit packs or integrated circuits in all stages of manufacture, handling, storage, shipping, installing, testing and maintenance can be instrumental in damaging or degrading these units by ESD. Static electricity can be generated by simple everyday tasks. The following figures indicate the amount of charge that can be built up and generated:

PROPRIETARY – BELLCORE AND AUTHORIZED CLIENTS ONLY
See proprietary restrictions on title page.

• Walking across linoleum	5,000 volts
• Walking across carpet	15,000 volts
• Working at a bench	800 volts
• Handling bubble plastic	20,000 volts
• Handling foam containers	11,000 volts

2. DEVICE SUSCEPTIBILITY

2.01 All components are sensitive to ESD. The degree of susceptibility and the level of sensitivity are governed by the circuitry and feature structure of the device, the design of the circuitry, and the manufacturing process applied to the device. Fine line designs, small junction features and thin dielectric structures are particularly sensitive to the high fields and/or discharge pulses associated with ESD. A more quantitative look at susceptibility is presented in Table 3. Here various device types are shown with the range of minimum voltages that can cause ESD damage to unprotected devices.

2.02 ESD failures are not always readily apparent; ESD failures frequently show no visible damage. Failures range from catastrophic to subtle electrical degradation that affects operating characteristics. ESD damage is not limited to integrated circuits. The failure effect in film resistors due to ESD is a change in resistance value and tolerance. Resistance can either increase or decrease depending on the original value and on the bulk resistivity of the film material. Changes in tolerance are most noticeable in precision film resistors. The very nature of electronic devices that makes them so useful (small size, low voltage, low power) is also what makes them so susceptible to ESD. Likewise, the advantages of the materials used in processes (silicon and its oxides) become concerns when considering susceptibility to ESD.

3. EQUIPMENT SUSCEPTIBILITY

3.01 There is more to equipment susceptibility than just the damage done to electronic devices. ESD can produce noise transients within the system wiring causing malfunction. For example:

- A terminal sends the wrong data to the main computer or completely loses the data.
- Memory in the main computer is changed causing parity errors or complete loss of program.
- Printers overprint or print garbled data.
- Disk and tape units "write" incorrect data.

These typical malfunctions can be caused by the Electromagnetic Interference (EMI) generated when ESD occurs. This wave of EMI, like a radio wave, spreads out in all directions from the point of static discharge. When the wave reaches conductive objects, a small electrical current is generated. These currents can cause the aforementioned malfunctions.

3.02 Metal housings for the equipment can be helpful in reducing EMI, but the energy can propagate into the circuits through discontinuities in the housing. Molded plastic cases may prevent damage from direct static discharges, but may allow damage that is induced by the radiated fields because plastic cases provide poor shielding to EMI. Also, the cables which interconnect the equipment may pick up the interference indirectly, regardless of the type of enclosure.

3.03 While the problems just discussed are by no means trivial, they are only part of the story. In addition to the damage caused by direct discharge of static electricity, other problems can arise just from the accumulation of static charge, even if ESD does not occur. With computers and related equipment, charge accumulation can cause problems such as printer malfunction and paper jamming and can cause dirt and other contaminants to be attracted to read/write heads and magnetic recording surfaces (disk and tape).

4. PREVENTIVE MEASURES

4.01 There are four steps to effective ESD protection and prevention:

PROPRIETARY – BELLCORE AND AUTHORIZED CLIENTS ONLY
See proprietary restrictions on title page.

(1) Identify the problem.

(2) Educate all persons involved.

(3) Implement corrective action.

(4) Monitor progress and follow-up as required.

The key to preventing ESD damage is to avoid the buildup of static charge. The best way to do this is by following careful handling procedures. Some useful suggestions are:

- Obtain a non-contacting electrostatic voltmeter, available commercially, to survey your own operation for static electricity hazards.
- Have all personnel wear grounded wrist straps when handling circuit packs not protected by antistatic packaging.
- Use only antistatic containers or packaging for shipping, storage and handling.
- Mark all containers or packaging materials with ESD warning labels (see Figure 1).
- Increase and control relative humidity. It is desirable to maintain humidity above 30 percent. The recommended minimum relative humidity level is 20 percent.
- Do not wax floors, but do use an antistat when damp mopping.
- Do not use carpeting in equipment areas or rooms with equipment electrically connected to electronic switching systems.
- Keep synthetic fibers, plastics, foams, etc., which are not antistatic, out of the environment where circuit packs or IC devices are going to be handled.
- Develop a static awareness program for all personnel who may contact sensitive devices.
- Always handle circuit packs by the front face; if additional support is needed, use the outermost top or bottom edge. Be careful not to touch integrated circuits or conductive paths. Never grasp the pack by the connector end.

5. WRIST STRAPS

5.01 Wear wrist straps when removing, inserting, or handling circuit packs not in antistatic packaging. The wrist strap should have a 1 to 12 megohm resistance in series at the wrist band end and a suitable device such as an alligator clip at the opposite end for connecting to an appropriate ground, such as bare metal. Most commercial wrist straps have a molded-in 1 megohm resistor near the wristband end. In 1/1A, 2/2B, 3 and 4ESS™ this can be accomplished by attaching the alligator clip to a mounting plate. In the 5ESS™ the alligator clip can be attached to the door latch. In the DMS-100* family the alligator clip can be attached to the ground lug. The wrist strap must be snug fitting and make contact with the skin. This provides a path to drain the static charge from the body.

5.02 Wrist straps should be checked weekly unless the failure rate indicates a need for more or less frequent testing. To assure proper circuit continuity and resistance, check end to end with an ohmmeter. See Figure 2 for the testing procedure.

6. ANTISTATIC PACKAGING MATERIALS

6.01 Cardboard boxes, molded foam containers, plastic bags, plastic sealing tape and loose fill cushioning material cause static electricity generation. These items should not be used to package circuit packs for storage or shipment unless the circuit pack is first protected by an antistatic bag.

6.02 Surface resistivity of antistatic plastics shall be less than 1.0×10^{13} ohms per square but greater than 1.0×10^{5} ohms per square on both surfaces as measured in accordance with ASTM-D-257** or equivalent.

™ ESS is a Trademark of AT&T Technologies, Inc.

* DMS-100 is a Trademark of Northern Telecom, Limited.

** American Society for Testing Materials ASTM-D-257. Standard test method for D-C resistance or conductance of insulating materials.

PROPRIETARY – BELLCORE AND AUTHORIZED CLIENTS ONLY
See proprietary restrictions on title page.

6.03 Packages should bear a WARNING label to indicate that contents are susceptible to damage from static electricity (see Figure 1).

7. ENVIRONMENTAL REQUIREMENTS

• Relative Humidity

7.01 Reports of static electricity problems generally increase with atmospheric dryness. In central offices these reports are most frequent when the relative humidity is below the 20 percent minimum specified in Practice 760-555-151. Merely raising relative humidity to this 20 percent minimum sometimes alleviates the static electricity problem. One way of improving both low and high humidity conditions is to minimize the intake of outside air. Periodic service checks of the humidification equipment should be scheduled to insure that the units are functioning properly at all times.

7.02 Operating the building within the recommended wideband temperature limits (SR 80-09-019) for heating and cooling (e.g., 65^{0}F to 80^{0}F) reduces the amount of outside air intake needed for cooling. Both high and low humidity conditions are alleviated. However, if the humidifiers are inoperative at any time during the normal heating season, the relative humidity can become less than 20 percent.

7.03 Review the specific switchroom or associated computer room environment for the capability to meet and maintain the specified operating requirements for relative humidity levels. In central offices, equipment room relative humidity should not be below the specified 20 percent minimum. For minicomputer rooms, humidity levels are specified in Practice 760-150-155. Raising the relative humidity above these minimum levels may improve but not necessarily eliminate static electricity problems.

• Floor Treatment

7.04 Walking on carpeted floors can generate static electricity. Therefore, the use of floor carpeting in minicomputer and telephone equipment rooms, and also in rooms containing equipment connected to telephone network equipment, ***is not recommended.*** Low-static carpeting has been recommended for use in administrative office space, but even this type of carpet should not be used in equipment rooms or in rooms with equipment electrically connected to the telephone electronic switching system (Practice 802-001-196).

7.05 Carpeting with metal strands is not recommended since ground faults and the compromise of single-point grounding can result. Antistatic spray is only a temporary expedient that causes dispersement of undesirable contaminants during applications.

7.06 Floor wax can add to static electricity generation. There is reason to suspect that some products labeled as floor finishes containing acrylic or other plastics generate static electricity more readily than some other products. Practices 770-130-055, 770-130-060, 770-130-070 and 770-140-010 describe floor finishes and maintenance procedures presently recommended. Practice 770-130-060 describes cleaning procedures for resilient floor coverings. Commercially available antistats added to cleaning water can provide temporary protection. Application of waxes or floor finishes will compromise these properties and is to be avoided.

7.07 For the selection and care of raised floors in equipment, administrative, or computer areas, specifications such as Practice 760-200-110 have been issued. Waxing of floors is not recommended. The only maintenance required is damp mopping with an antistat added to the water.

7.08 Perform a resistivity level test with a suitable megohmmeter for measuring surface resistance on the floor covering and furniture materials. Surface resistivity is a factor in limiting electrostatic voltage build-up on people. The test methods specified in National Fire Protection Association (NFPA), 56A Section 4628, or in ASTM (American Society for Testing Methods) F 150-72 may be used to measure floor surface resistivity. For regular tile or linoleum floors the acceptable range is roughly 10^{5} to 10^{12} ohms per square. Acceptable limits for a raised floor system would be 150,000 to

PROPRIETARY – BELLCORE AND AUTHORIZED CLIENTS ONLY
See proprietary restrictions on title page.

20×10^{10} ohms per square.

7.09 An alternative to measuring floor surface resistivity is to measure static voltage buildup on a person walking across a floor. The test method is an adaptation of the AATCC (American Association of Textile Chemists and Colorists) Test Method 134-1975. Suitable electrometers for approximate measurements of surface static voltages are listed in the AATCC Test Method. After a person walks across a section of flooring in a normal manner, aim the electrometer at the person from the recommended distance and measure the static voltage stored on the person. Acceptable maximum limits are approximately 3000 volts for human comfort and 1000 volts for susceptible equipment protection.

• Air Filtration

7.10 Review the air filtration control equipment to ensure that it can meet or exceed the minimum requirements. Minimizing outside air intake or infiltration into the building will help to maintain humidity within these limits during either low or high outdoor humidity conditions.

8. STORAGE, MOVEMENT WITHIN OFFICE, AND SHIPPING

• Storage

8.01 All packages received containing circuit packs with sensitive integrated circuitry should have WARNING labels. The labels indicate that special handling is required. These circuit packs should remain in the antistatic packaging material while in storage. If the circuit pack is to be removed from this packaging for any reason, the person should be properly grounded; i.e., wearing a wrist strap attached to an appropriate ground as indicated in Paragraph 5.01.

8.02 It is suggested that circuit packs be left in their individual packing containers and stored in metal cabinets with doors. These containers will provide protection from both mechanical and electrostatic discharge damage while in storage and when moving the circuit packs from one location to another. The containers will then be available for shipping defective circuit packs back to Plug-In Inventory Control System (PICS) or repair locations.

8.03 If KS-22294 storage racks are being used, the circuit packs will have to be removed from their individual packing containers; however, they should be left in their antistatic plastic bags. In this situation care must be taken when transporting the circuit packs in their antistatic bags from the storage facility to another location. To avoid mechanical damage to the components, circuit packs should not be stacked on top of one another without adequate protection between the circuit packs.

• Movement Within Office

8.04 When removing circuit packs from storage facilities care should be used so as to not damage components. The circuit packs should remain in the antistatic packaging and the cardboard containers (if available) until ready to insert in the frame. A suggested method for handling circuit packs is as follows:

(a) Remove circuit pack from storage location in original container. If stored in racks this will be the antistatic bag only.

(b) Carry circuit pack to frame location. If in antistatic bag only, additional care must be taken to protect from mechanical damage. Handle by face plate only.

(c) Attach wrist strap to appropriate ground. (Refer to Paragraph 5.01.)

(d) Remove circuit pack from container, remove antistatic bag, place antistatic bag on top of container and lay circuit pack on antistatic bag.

(e) Remove defective circuit pack from frame, exchange circuit packs, lay defective circuit pack on antistatic bag and insert new circuit pack into frame.

(f) Insert defective circuit pack into antistatic bag, then into cardboard container for return

PROPRIETARY – BELLCORE AND AUTHORIZED CLIENTS ONLY
See proprietary restrictions on title page.

to PICS or repair location.

• Shipment

8.05 All circuit packs should be properly protected before shipment. In addition to antistatic packaging, cushioning material should be used to assure that the circuit packs are protected from mechanical damage. Defective circuit packs should be handled with the same precautions as a new circuit pack, thereby reducing the possibility of added damage.

8.06 Antistatic packing pellets or bubble material may be used to prevent the circuit packs from shifting inside the carton or shipping container.

9. REPAIR LOCATIONS OR WORK STATIONS

9.01 When performing repair operations (i.e., in a PICS location) all static-sensitive devices and components must be handled in a static-safeguarded work area. Such an area should be equipped with the necessary protective materials and equipment to limit and control static charge accumulation to levels which will not damage sensitive devices. This is accomplished by the use of suitable grounding materials and techniques for all conductors (including people) and by the use of ionized air to neutralize static charges on nonconductors. Suitable grounding materials in a work area include wrist straps and ohmic* table tops. All protective materials should be electrically connected to a common ground system.

9.02 The following suggestions pertain to setting up a static-safeguarded work area:

- All work surfaces must be ohmic. Bulk ohmic materials are better than hygroscopic (humidity dependent) materials because the electrical resistance is more uniformly distributed. This uniform resistance provides for better static charge dissipation.
- All ohmic objects should be electrically connected to a common ground point through a 1 megohm resistance.
- All personnel handling electronic circuitry must be connected to ground. This is best achieved by a grounded wrist strap which must contact the person's skin. For safety reasons, this ground connection must include a 1 to 12 megohm series resistance. Do not pass a sensitive device to a person who is ungrounded.
- All nonconductive items in the work area should be replaced by antistatic or ohmic ones. This includes trays and other containers, bags, workholders, visual aids, and other shipping, packing, and handling materials. If nonconductive items must be used, ionized air should continuously flow across the work area to neutralize static charges.
- Any tools or equipment in the work area should be grounded. This includes soldering irons and lead-forming tools.
- No food should be allowed in a static-safeguarded work area. Plastic wrappers and cups are excellent static charge generators.
- Ohmic flooring should be used in any area where static-sensitive devices are handled.

9.03 Upon entering a static-safeguarded work area, a person should first put on a wrist strap to remove any accumulated static charge and follow these precautions:

- Printed circuit boards or circuit packs should not be removed from systems with the power on.
- Static-sensitive devices which are thought to be defective should be handled with the same precautions as for other static-sensitive devices. If a faulty device is further damaged by ESD during examination, the cause of the original failure may never be determined.

* In this context, ohmic refers to a material with a distributed resistance of 10^4 to 10^{10} ohms per square.

PROPRIETARY – BELLCORE AND AUTHORIZED CLIENTS ONLY
See proprietary restrictions on title page.

- All repaired items should be handled with the same protection as new products.
- Adhesive sealing tape should not be used near static-sensitive devices. The action of removing a strip of tape from the roll can generate enough static charge to damage devices.
- Some ohmic materials are susceptible to a decrease in conductivity as a result of surface abrasion, friction or heat. Periodic tests should be made to verify conductivity.

10. STRESS TESTING

10.01 Antistatic plastic sheeting should be used when performing heat and stress testing as described in Practice 201-021-001. Antistatic plastic materials should not be reused for subsequent tests since exposure to the high temperatures will probably cause the antistatic qualities of the plastic to be reduced.

PROPRIETARY – BELLCORE AND AUTHORIZED CLIENTS ONLY
See proprietary restrictions on title page.

Table 1 - TRIBOELECTRIC SERIES

Asbestos	Acquires a more positive charge
Acetate	
Glass	
Human Hair	
Nylon	
Wool	
Fur	
Lead	
Silk	
Aluminum	
Paper	
Polyurethane	
Cotton	
Wood	
Steel	
Sealing Wax	
Hard Rubber	
Acetate Fiber	
Mylar	
Epoxy Glass	
Nickel, Copper, Silver	
401 Epoxy Resist	
UV Resist	
Brass, Stainless Steel	
Synthetic Rubber	
Acrylic	
Polystyrene Foam	
Polyurethane Foam	
Saran	
Polyester	
Polyethylene	
PVC (vinyl)	
KEL F	
Teflon	
Viton	Acquires a more negative charge
Silicone Rubber	

PROPRIETARY – BELLCORE AND AUTHORIZED CLIENTS ONLY
See proprietary restrictions on title page.

Table 2 - ITEMS THAT GENERATE ELECTROSTATIC CHARGES

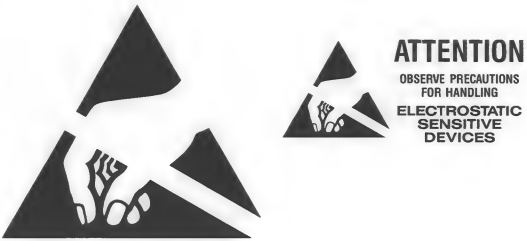
WORK SURFACES
• Formica • Finished Wood • Synthetic Mats • Ungrounded metal plates • Glass
FLOORS
• Vinyl • All waxed floors
CHAIRS
• Fiberglass • Plastic • Vinyl or Fabric covered • Ungrounded metal • Finished wood
CLOTHING MATERIALS
• Wool • Synthetics • Silks • Jersey
PART AND ASSEMBLY PACKAGING MATERIALS (untreated)
• Polyethylene bags and film • Polyethylene bubble pack and foam • Polyurethane packaging pellets • Plastic trays, boxes, vials, cabinets

PROPRIETARY – BELLCORE AND AUTHORIZED CLIENTS ONLY
See proprietary restrictions on title page.

Table 3 - SUSCEPTIBILITY RANGES OF VARIOUS UNPROTECTED DEVICES SUBJECTED TO ELECTROSTATIC DISCHARGE

DEVICE TYPE	RANGE OF ESD SUSCEPTIBILITY (VOLTS)
MOSFET	100 to 200
JFET	140 to 10,000
CMOS	250 to 2,000
Schottky Diodes, TTL	300 to 2,500
Bipolar Transistors	380 to 7,000
ECL (for Hybrid Use, PC Board Level)	500
SCR	680 to 1,000

PROPRIETARY – BELLCORE AND AUTHORIZED CLIENTS ONLY
See proprietary restrictions on title page.



Labels found on packaging
of DCT channel units and
common group plug-ins

CAUTION

THIS MODULE CONTAINS INTEGRATED CIRCUITS WHICH ARE EASILY DEGRADED BY STATIC DISCHARGES.

WHEN HANDLING THIS UNIT PROPER ANTI-STATIC MEASURES SHOULD BE TAKEN SUCH AS WEARING GROUNDING BRACELETS AND HANDLING BY THE FACEPLATE ONLY.

Figure 1 – **SAMPLES OF LABELS**

PROPRIETARY – BELLCORE AND AUTHORIZED CLIENTS ONLY
See proprietary restrictions on title page.

The molded plastic snap housing at the end of ground lead contains a 1 megohm plus/minus 10%, ½ watt resistor. To test the cord, resistance values can be checked between metal snap connector and the ground clip using a standard ohmmeter. Set ohmmeter on 1K ohm setting. Strap should measure greater than 500,000 ohms (500 on meter scale) and less than 1,100,000 ohms. Usual reading will be approximately 800,000 ohms.

WARNING

Measurement is to be taken from snap clip on cord.
DO NOT measure from wrist strap material.
See figure below.

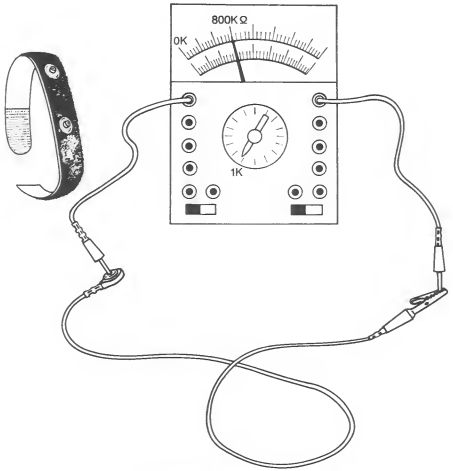


Figure 2 — **WRIST STRAP TEST METHOD**

PROPRIETARY – BELLCORE AND AUTHORIZED CLIENTS ONLY
See proprietary restrictions on title page.